THE RECURRENT LARYNGEAL NERVES IN THYROID SURGERY

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By
WILLIAM H. RUSTAD, M.D.

Assistant Clinical Professor of Surgery
University of California School of Medicine
Visiting Staff (Surgery) University of California Hospital
Staff Member St Luke's, Mt Zion, and Hahnemann Hospitals
San Francisco, California

Illustrations by
RALPH SWEET



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Introduction

NEARLY two thousand years ago Galen warned the young physician, "if on dissecting a part, you discover something which differs from my description, you should ascertain whether it is a rarity. Hence, you should refrain from condemning any works until, like myself, you have investigated many bodies." [ἐὰν καὶ σοί ποτε μέλος ἀνατέμνοντι παρὰ τὰ γεγραμμένα πρὸς ἡμῶν φανῇ τι, γίγνωσκε τοῦτο τῶν σπανίων ὑπάρχον. διόπερ οὐδὲ προκαταγιγνώσκειν σε χρὴ τῶν πεπραγμένων πρὸς ἡμῶν, ἄχρι περ ἂν αὐτὸς καὶ σύ, καθάπερ ἡμεῖς, ἴδῃς πολλάκις. *Ad anat.*, I:XI (Kühn, II, 278.)] With these words began the pursuit of individual variation in the anatomy of man, a pursuit which has continued with an increasing importance as more and more individuals are subject to surgical procedures.

The recent recognition that many of the post-operative derangements of laryngeal function are due to damage of the branches of the recurrent nerve, hitherto generally regarded as a single nerve, compels the surgeon to keep in mind the variations in distribution of this nerve just as he must in the case of the biliary and urinary tracts To this moment, data on the variability of the recurrent nerve has been scanty. The present study by Dr Rustad remedies this deficiency. By careful, arduous and painstaking dissection he shows us how incomplete has been our knowledge of the plain anatomy of this important nerve. Apparently the region is one in which variation is the rule. Dr. Rustad has wisely presented his findings in the simplest form which may serve to emphasize the fact that the surgeon operates on the individual and not on a statistic and hence familiarity with all possible alterations of arrangement are essential if he is to avoid errors of diagnosis and operative technique This contribution is of first importance to the thyroid surgeon.

J. B de C. M Saunders, F.R C S
Professor of Anatomy and
Chairman of the Division
Dean of the University of
California School of Medicine

Preface

THE BASIC objective of this study was to dissect an adequate number of cadavers in order to obtain a truly representative picture of the anatomy of the extralaryngeal portion of the recurrent laryngeal nerves on the right and left sides of the neck. No attempt has been made to follow the distribution of the nerves once they had entered the larynx. We were concerned solely with the extralaryngeal portion of these peripheral nerves.

It was decided arbitrarily that 250 nerves would make such a representative picture and, accordingly, 125 cadavers were studied. These cadavers were dissected in the Anatomy Laboratories of the University of California at Berkeley, California, and the Anatomy Laboratory at Stanford University, Palo Alto, California. The availability of cadaver material being somewhat limited, the study required the span of three years before 125 cadavers could be dissected, the recurrent laryngeal nerves carefully exposed, and their courses individually transposed onto a basic line drawing done in the laboratory while actually looking at the dissected specimen The principal use of these cadavers was for the teaching of general anatomy to First Year medical students of both universities. The students were requested not to disturb the area normally traversed by the recurrent laryngeal nerves, but in a few instances, this area had been invaded out of curiosity. In some of these cases the nerve filaments were occasionally torn, or the *inferior thyroid* artery was torn and the relationship of these structures to each other could, therefore, not be reconstructed After we had eliminated this type of case from the study we had approximately 110 undisturbed specimens. We elected to report on 100 simply because the number was an even one, and facilitated the calculation of percentages.

As stated above, all the dissections depicted in this monograph were done in the laboratories of these two universities at times when the teaching staffs of the respective Anatomy Departments were in attendance. Unusual specimens, of course, were objects of great interest and curiosity and were shared, and then confirmed in each instance by several observers

After the course and relationships of the recurrent laryngeal nerves were traced out on the basic line drawing, they were filed until the entire dissection program was complete In those instances where it was difficult to show peculiarities of the relationship by drawing alone, verbal descriptive matter was written on the paper at the time of completion of the particular

Acknowledgments

AFTER considerable reflection on the output of effort that has gone into the preparation of this very small monograph and the subject material contained therein, it is quite impossible for me to conceive that any book or piece of research can be accomplished by one man, himself. There are those who actually assisted me in the time-consuming dissections involved and there are those who, through their position of preeminence made the way clear for this work to proceed When money was needed, there were those who made certain budget accounts available. In the preparation of any book there is always the greatest of all work horses, namely: the typist, with aching arms, tired back and sore fingers. And, finally, there are those whose encouragement and vital interest in the project are ever present with these important spiritual influences that never permit one to leave the task unfinished.

My appreciation is extended to John B. deC. M. Saunders, Professor of Anatomy and Chairman of the Department of the University of California, for his multi-facetted assistance. Dr. Saunders, as head of the Department, cleared the way for the availability of cadaver material and provided an ever-present, stimulating interest in this work. I belabored him for the proof-reading of the final manuscript and for suggestions and improvements in this phase of the work. To his immediate associate, Dr. William Rhinehart, Professor of Anatomy and in charge of the Anatomy Laboratory of the Berkeley Campus, goes my sincere thanks for expediting the prolonged dissection phase of the work, for his keen interest and stimulation in the laboratory and for the preservation of the specimens for my study.

Dr Rhinehart's counterpart at Stanford University, in Palo Alto, is Dr. Donald Gray. Dr Gray was helpful in the extreme and exhibited a warm, friendly cooperation that permitted us to carry out our dissections on his cadaver material. He made us feel right at home and our thanks are genuinely expressed for his significant contribution.

To Dr. Lewis Francis Morrison, I express my sincere gratitude. Dr. Morrison made all the percentage calculations found in the tables, derived from the figures, produced at the dissection table, and gave assistance in the preparation of the manuscript. It was through the kindness of Dr. Morrison and other officers of the American Laryngological, Rhinological and Otological Society, Inc, that I was invited to present a preliminary report on

dissection. Thus it was possible always to maintain a literal, fresh recollection of the situation as it was seen to have existed. When the entire dissection program had been completed, all of the drawings were classified Those nerve, artery, thyroid gland relationships that were different, each from the other, were put into a separate group. There were 87 such specimens, and these were then reproduced in a final artistic form by Ralph Sweet, Chief Medical Illustrator of the University of California Hospital and the School of Medicine. These are the drawings to be seen in the monograph. No two are exactly alike, and the descriptive material accompanying them has been taken from the original written description made at the time of the specific dissection.

WILLIAM H. RUSTAD

San Francisco, California

Contents

the results of this work, in Los Angeles in January of 1950. As Professor of Otorhinolaryngology at the University of California School of Medicine, Dr. Morrison was in a position to lend financial assistance through the devious channels of University finance. Finally, Dr. Morrison made available two of his assistant residents, training in the Department of Otorhinolaryngology, to assist me with the actual dissection work.

It was my personal pleasure to spend many hours in the Anatomy Laboratory with Dr. Raymond C. Arnold, and Dr. Bruce G. Whitaker, who were then in Resident training in the Department of Otorhinolaryngology under Dr. Lewis Francis Morrison at the University of California Hospital and the School of Medicine They were unstinting and generous beyond the call of duty in their donation of time and careful effort in assisting with the dissections. Together the three of us viewed, studied, analyzed and commented upon every specimen that was at all unusual. The assistance given by Dr. Arnold and Dr Whitaker is profoundly appreciated.

I feel confident in my belief that Mrs. Olive Neick knows more about the Recurrent Laryngeal Nerves than any other lay person in the entire world. Mrs. Neick labored at night. Mrs. Neick labored early in the morning. Mrs. Neick labored all day in the preparation of the manuscript through its many revisions and changes Mrs. Neick made her time available on Saturdays and Sundays and almost any time to coincide with my own time, to write and rewrite and change and change once again the manuscript. Her warm personal interest and selfless devotion to getting the job done was a real factor that cannot be overestimated. I am sure that she is aware of the inestimable value I place on her particular role.

In the final instance, when all other acknowledgments are made, my deepest thanks go to W B for her special contribution.

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CHAPTER 1

Historical Background

IN 1948, Brien T. King, M.D. (19) of Seattle, Washington, published the results of a series of special dissections and experiments he had been conducting which have seemed to raise the shroud of mystery and unexplained phenomena from certain phases of laryngeal behavior, especially the derangement of laryngeal function following damage to one or both recurrent laryngeal nerves. Dr. King's findings are of such importance as to have made it desirable to extend his observations, since they were made on a dissection experience of only sixteen cadavers Therefore, we undertook our own separate investigation of this subject at the University of California School of Medicine

The foundation of the entire current understanding of laryngeal function is based on the work of Onodi (38) and Lemere (22, 23, 24, 25). Their contribution to the knowledge of this subject was a series of detailed studies on the intrinsic anatomy and physiology of the larynx. Their work is nothing short of monumental, since it has paved the way for the subsequent appreciation and clarification of laryngeal function under both normal and abnormal conditions For the past several years and at the time of the present writing, Murtagh (31, 32, 33) has carried out extensive studies along the same lines as those of Onodi and Lemere. Not only has Murtagh studied the larynx from a gross anatomical point of view but has, by physiological techniques, investigated the function of the laryngeal muscles, and in addition, has followed by histologic sections the distribution of the recurrent nerves within the larynx He has been able to confirm the teachings of Onodi and Lemere

The extralaryngeal portion of the recurrent nerves has been the object of extensive study by anatomists and surgeons of many ages and their contributions to the literature on the subject are indeed voluminous, if not always illuminating

Outstanding among these many contributors have been Nordland (37), Fowler and Hansen (8), and Berlin and Lahey (2, 3), but it was not until 1948, when Dr King made his epochal contribution to the understanding of laryngeal innervation and its role in laryngeal function, that students of this subject really began to appreciate the significance of their findings

There have been many references made to the historical background of our knowledge of laryngeal function and behavior, but nowhere can one find such an excellent summary of this entire background of this subject as is contained in a recent paper of Morrison (30). Anyone interested in this particular phase of the subject can do no better than to review that article. Morrison compiled a chart in chronological sequence which I have borrowed outright and which I include at this point I have found this chart interesting and informative, and it is given here as a succinct review of the historical background.

CIRCA, A.D. *100*	RUFUS THE EPHESIAN Greek anatomist. Treatise on Nomenclature on Parts of the Human Body. Aphonia and respiratory distress associated with injury of the recurrent laryngeal nerves.
160-200	GALEN. The first recorded observations on experimental paralysis of the recurrent laryngeal nerves Animals . . . aphonia and respiratory distress.
1514-1564	VESALIUS (49). Interested in the role the recurrent laryngeal nerves played in voice production. Experimental work and drawings of the human larynx showing the structures and the superior and recurrent laryngeal nerves
1734	MARTIN (28). Animal experiments Return of voice (dog) due to communicating branches of the superior and recurrent laryngeal nerves
1792	HAIGHTON (10) Believed that the severed ends reunited
1813	MAGENDIE. First to demonstrate experimentally that the crico-thyroideus was innervated by the superior laryngeal nerve.
1823	STEDMAN (52) Anomalous right recurrent nerve Explanation was not adequate
1826	HART (11). Irregular origin of the right recurrent laryngeal nerve. Secret of the circuitous route was to be found in the natural law of embryonic development
1828	RAINEY (42) Anomalous right recurrent laryngeal nerve.
1832	MECKEL (29) First to make mention of a divided recurrent laryngeal nerve Rare but when it did occur it is always on the right side.
1836	LEY. Fertile imagination as to the function of the cricoid cartilage
1836	MAGENDIE (27) Anatomists unable to explain why the recurrent laryngeal nerve took such a complicated course
1837	HILTON (13). Anomalous right recurrent laryngeal nerve
1838	REID (44). One of the first to present experimental studies

that approached completeness and were of *scientific* value.

1846 Hérard (12). Anomalous right recurrent nerve.

1847 Reid (43). Gave correct explanation of the origin of the anomalous recurrent nerves.

1848 DeMarquay. Anomalous recurrent laryngeal nerve.

1869 Philipeaux (40) and Vulpian. Anastomosing fibers when present come from the superior laryngeal nerve.

1871 Luschka (26). No communication between the superior and recurrent laryngeal nerves even though they might share the same sheath for short distances.

1876 Habershon (9). Communications between the superior and recurrent laryngeal nerves.

1879 Woelfler (54). Dissections. Nerve always anterior to the artery.

1881 Semon (50, 51). Formulated and presented his Law.

1883 Kocher (20). Dissections. Artery posterior to the nerve

1884 Exner (7). Elaborate monograph.

1885 Rotter (46). Dissections, 15 Only one-third followed the pattern described by Kocher.

1886 Streckeisen (53). Dissections, 56. Mainly interested as to whether or not the artery formed a loop around the nerve

1887 Hooper (14). Excellent article . . both historically and practically.

1892 Russell (47). Substantiated Semon

1906 Grossmann In certain cases of paralysis the cords assume the cadaveric position due to the atrophy of disuse of the crico-thyroid muscle Work has not been confirmed

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vocal cord toward the midline. This being true, it is now agreed that the crico-thyroideus has also a definite adductor function. This fact was clearly pointed out in earlier contributions by Wagner, Onodi and Lemere and more recently by Iglauer and Murtagh. These researchers agree that it is the adductor function of the crico-thyroideus that maintains the cord in the median or para-median position following complete recurrent laryngeal nerve paralysis.

The fourth set of muscles are those exerting a constrictor function on the larynx. These are the musculae aryepiglottici.

It is elementary to state that the ability of the laryngeal muscles to carry out their several functions is dependent on their nerve supply. There is now complete agreement between those who have devoted the greatest attention to this subject that the nerve supply to the larynx is as follows:

(a) The recurrent laryngeal nerve, right and left, supplies all of the muscles of the larynx *except the crico-thyroid*

(b) The crico-thyroid muscle receives its innervation from the external branch of the superior laryngeal nerve. This, then, is the total motor innervation to the larynx. The internal branch of the superior laryngeal nerve supplies all of the sensation to the mucosa of the larynx. It has no efferent fibers but rather is composed entirely of afferent fibers It has been irrefutably demonstrated that the fibers of the internal branch of the superior laryngeal nerve do not supply any motor function to any muscle nor do they communicate or anastomose with any motor nerve to the larynx. They do not contribute in any degree any nerve supply to the inter-arytenoideus muscles but merely traverse the inter-arytenoideus in order to reach their destination—the mucous membrane of the larynx

For the sake of emphasis, it is well to say at this point that not only is the literature but so also are standard textbooks replete with many descriptions of communications and anastomoses between the internal and external branch of the superior laryngeal nerve and protean communications between the recurrent laryngeal nerves All of these presumed anastomoses have no existence and were assumed to occur in an attempt to explain phenomena which were little understood.

CHAPTER 2

Laryngeal Muscles and Their Nerve Supply

THE LARYNX is a musculo-cartilaginous organ whose functions, according to Negus (34, 35) are three:

1. Protection of the respiratory tract distal to the vocal cords against the ingress of foreign particles, especially during the act of swallowing.
2. Maintenance of a patent airway.
3. *Vocalization*

Function One depends on the integrity of all the intrinsic laryngeal muscles except the cricothyroid and the *posterior cricoarytenoid.*

Function Two depends only on the posterior cricoarytenoid muscle and Function Three requires all but the posterior cricoarytenoid muscle.

The functions of the larynx mentioned above are carried out by four sets of muscles, to wit:

1. The adductor muscles.
2. The abductor muscle.
3. *The tensor muscle.*
4. The constrictor muscles.

The lateral cricoarytenoid muscle is one of the adductor muscles whose function is to bring into a position of adduction the anterior half or two-thirds of the vocal cord of the same side

The interarytenoid muscle is another adductor whose function is to bring into a position of adduction the posterior half or one-third of the vocal cord of the *same side.*

The thyro-arytenoid muscle is also one of the adductor muscles whose function is to adduct the cord and relax it

The posterior crico-arytenoideus is the one and only abductor muscle of the larynx and therefore the function of this muscle is to abduct the cord laterally, thereby dilating the glottis and providing a patent airway

The crico-thyroid muscle is primarily a tensor of the vocal cord of the same side. *Contraction* of the crico-thyroid muscle enlarges the glottis in the antero-posterior diameter and in so doing tenses the cord on that side During the course of this action, there is an inevitable movement of the

the right. The nerve continues its cephalad course in the tracheo-esophageal groove as a single trunk, and after coursing well posterior to the thyroid gland, it ascends alongside the cricoid cartilage and enters the larynx in the immediate vicinity of the inferior cornu of the thyroid cartilage.

The right recurrent laryngeal nerve, like its homologue on the left side, is also derived from the main trunk of the right vagus nerve. It leaves the parent nerve at the level of the right subclavian artery and therefore hooks around this vessel and begins its ascending course. The right recurrent laryngeal nerve is universally described as occupying a slightly more lateral position with relation to the midline than the nerve on the left side. It therefore approaches the tracheo-esophageal groove from this somewhat lateral position and ascends to enter the larynx in the same manner as the nerve of the opposite side. This, then, constitutes the description of the origin and course of these nerves as it has been handed down from generation to generation.

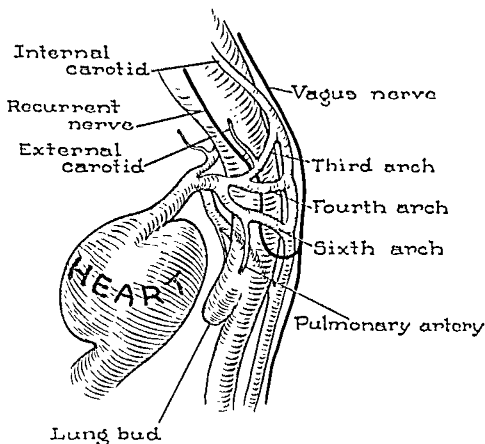


FIGURE 1

Chapter 3

The Recurrent Laryngeal Nerves

As IS TRUE of all nerve tissue, the recurrent laryngeal nerves are ectodermal in origin and are present near the beginning of fetal life. At an early stage of embryonic development, they have a transverse direction, and proceed directly from the vagus in a horizontal plane to their ultimate distribution. Their later recurrent course is determined solely through developmental changes in the aortic system of arches, and to the descent of the heart into the thorax.

The recurrent laryngeal nerves originally passed under the sixth pair of aortic arches, but as the ductus arteriosis—the sixth arch on the left side—is obliterated after birth, it follows that the left recurrent nerve is hooked under the first permanent arch above it, namely the fourth, which has become the arch of the aorta; while on the right side, the fifth and sixth aortic arches disappear entirely, and the right recurrent nerve consequently passes under the fourth aortic arch, which persists as the right subclavian artery (Hooper, 14). The period of development of the aortic arches extends throughout the fifth week of fetal development and their transformation mainly occupies the sixth and seventh weeks

The first and second pairs of aortic arches drop out early and are replaced respectively by mandibular and stapedial vessels (Arey).

The third pair of arches adjust themselves in such a way as to form ultimately the carotid system of vessels and their important tributaries

The fourth pair of arches are permanent and persist as the arch of the aorta on the left and right subclavian on the right

The fifth aortic arches disappear early

The sixth aortic arch on the right atrophies and disappears entirely, while its fellow on the left persists as the Ductus Arteriosus of Botallo, patent in fetal life, but atrophied in post-natal life

In the normal human post-natally, the left recurrent laryngeal nerve is derived from the parent vagus nerve on the same side and leaves the vagus nerve at a point just below the arch of the aorta The nerve courses around the arch of the aorta and assumes a cephalad direction. It tends to approach the trachea and esophagus rather early and therefore at the root of the neck the left recurrent nerve generally lies closer to the midline than does

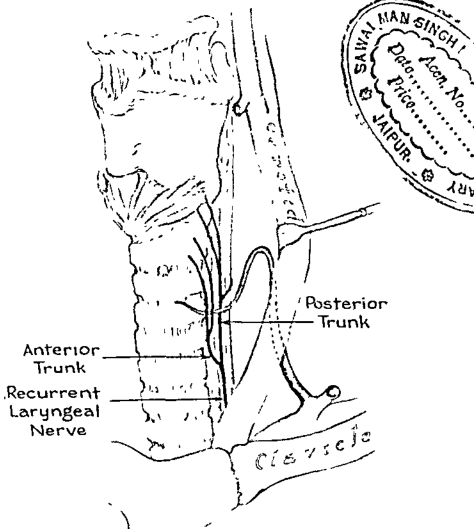


FIGURE 3

four to six bundles and frequently divides intralaryngeally into as many as twelve bundles of nerve fibers.

From this we can then assume that if we saw in some rare anatomical specimen a recurrent laryngeal nerve that divided extralaryngeally into twelve branches, we need not be too surprised.

We may draw the analogy of a huge pipeline bringing the water supply to a community from a far distant lake and then breaking up into smaller conduits as the community is approached, and ultimately breaking down into single conduits supplying a unit of that community. In this instance, we have a community of laryngeal muscles receiving their nerve supply from the large principal conduit, the recurrent laryngeal nerve. In order that each unit of this community of muscles may receive its own nerve sup-

We have considered the recurrent laryngeal nerve to be a single trunk nerve when it ascends from the thorax, traverses the neck and enters the larynx without having branched at any point (with the exception of tracheal and esophageal branches). We have considered the nerve, on the other hand, to be a divided nerve if the point of division was extralaryngeal, irrespective of the point at which it divided.

Our investigations have confirmed the investigations of others, namely that the recurrent laryngeal nerve frequently divides into two branches.

That portion of the work of Murtagh (33) devoted to the histologic studies of the intralaryngeal distribution of the recurrent laryngeal nerve has shown clearly that the nerve, intralaryngeally, invariably breaks up into

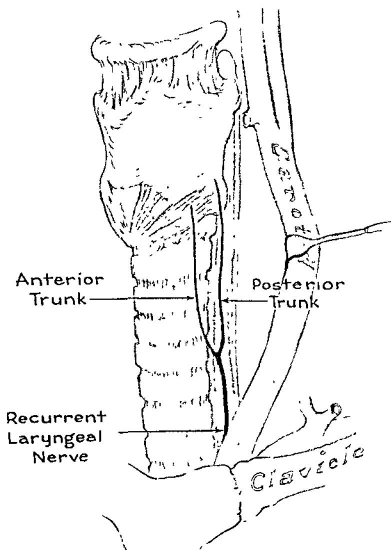


FIGURE 2

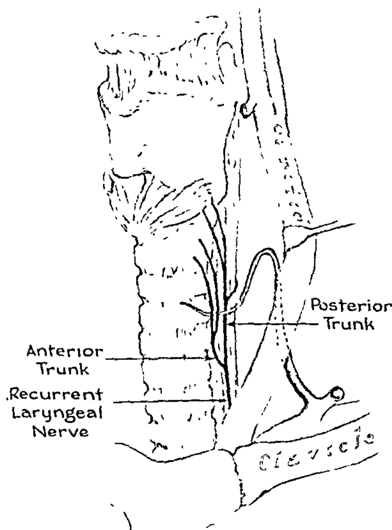


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ply, it is clear that this one large conduit must divide and re-divide in order to supply the individual unit of the community of muscles. This division and subdivision often takes place intralaryngeally, but we now know and recognize that it can take place anywhere peripheral to the initial branching from the vagus.

According to Murtagh, the actual number of fibers in a single nerve will depend on the level at which the section is made. There are invariably more fibers peripherally than centrally, as long as sections include the entire nerve. The relatively larger and more heavily myelinated fibers constitute the greater number of fibers in these bundles and it is these larger and more heavily myelinated fibers which make their way to and lend their

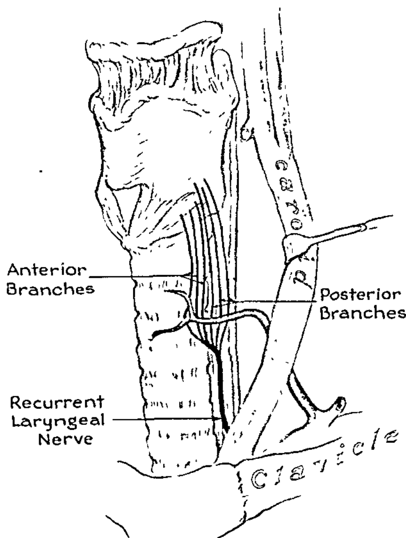


FIGURE 4

nerve supply to the muscles concerned with the function of adduction. The smaller and less heavily myelinated fibers are considered as supplying the abductor muscle. There is no histologic or physiologic evidence at this time that the abductor fibers or the adductor fibers are contained in separate bundles within the recurrent laryngeal nerve. An analysis of the experience with damaged recurrent laryngeal nerves reveals that the adductor fibers are more commonly damaged than the abductor fibers. It would appear that the reason for this lies simply in the fact that, in general, these fibers occupy a more anterior position in the total nerve bundle. They are therefore, "closer to the line of fire" or the field of action—the thyroid gland which is being operated upon.

The damage suffered by the nerve supply under discussion is, of course, a lower motor neuron type damage followed by flaccid paralysis and subsequently characterized by atrophy, fibrosis and contracture in that order.

Our dissecting room experience has revealed that the recurrent laryngeal nerve is not limited to the possibility of dividing into two branches only, but we have actually seen one instance where the recurrent laryngeal nerve divided extralaryngeally into six branches, all of which were clearly and unmistakably seen to enter the larynx.

We have seen 67 specimens (77.91%) where the recurrent laryngeal nerve has divided into two branches We have seen 9 specimens (10.46%) where the recurrent laryngeal nerve has divided into three branches, 7 specimens (8.14%) where the recurrent laryngeal nerve has divided into four branches; 2 specimens (2 32%) where the recurrent laryngeal nerve has divided into five branches, and finally, 1 instance mentioned above, where the recurrent laryngeal nerve divided into six terminal branches.

TABLE I

Number of Divisions of Divided Nerves

(86 Nerves)

Number of Branches		2	3	4	5	6
Right		40	4	6	1	
Left		27	5	1	1	1
	Total	67	9	7	2	1
Per Cent		77 91	10 46	8 14	2 32	1 16

All of these divisions occurred extralaryngeally and all branches were seen to enter the larynx. The nerve was found to undergo extralaryngeal division bilaterally in 24% of the cadavers examined by us, and was found to undergo division unilaterally in 43% of the cadavers. In order to create a basis on which we could analyze the level at which the recurrent laryngeal nerve divided, we chose the thyroid gland as the principal point of

TABLE II

Single Trunk Nerves (114)			57%
Right	58	29%	
Left	56	28%	
Divided Trunk Nerves (86)			43%
Right	44	22%	
Left	42	21%	
		Total 200 nerves	

remain 65 examples of nerve division in areas frequently invaded during neck surgery. In other words, more than one-third of the patients can be expected to have one or more divided nerve trunks at the thyroid or inferior thyroid levels and therefore one-third of all patients possess potentiality for injury of one or the other of the main trunk branches of the recurrent laryngeal nerve

TABLE III

Bilateral Single Trunk Nerves	(70)	35%
Bilateral Divided Trunk Nerves	(48)	24%
Mixed Single and Divided Trunk Nerves	(82)	41%

relationship. That area of the neck normally occupied by the isthmus and main substance of the thyroid gland we have designated as the thyroid level. The area usually occupied by the superior pole we have designated as the superior thyroid level, and the area occupied by the inferior pole of the thyroid gland as well as the area distal to this point as the inferior thyroid level.

A summation of these figures shows that of the 200 nerves 86 or 43% were either unilaterally or bilaterally divided nerve trunks. If one deletes those that divide high in the superior thyroid level, some 21 in number, there still

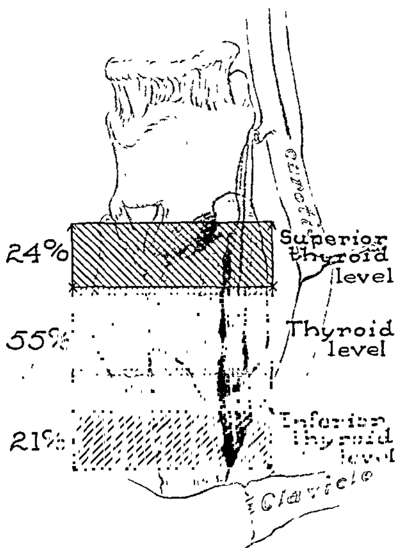


FIGURE 5

this structure. We are in disagreement with the concept that the recurrent laryngeal nerve ever penetrates the substance of the thyroid gland. We have seen instances where adenomas have appeared to grow around or curve around the main trunk of the recurrent laryngeal nerve, but careful dissection has proven that the nerve did not penetrate the gland substance proper, even though it was obviously in close relationship. Embryologically, we consider that it is impossible for the recurrent laryngeal nerve to traverse the gland parenchyma. We, however, are in agreement with these authors when they say that the inferior cornu of the thyroid cartilage represents a good landmark for the location of this nerve, since the recurrent laryngeal nerve generally passes just posterior to this articulation.

The author feels that it would be extremely easy to miss the presence of a divided nerve in the live patient during the course of operation, for the surgeon, quite naturally, upon discovering a branch of the recurrent nerve trunk, would presume this to be the nerve *in toto* and would terminate his dissection rather than lay open all the tissue spaces in the neck in search of a possible second or third branch. It is therefore only in the cadaver where the entire area extending from the pre-vertebral fascia all the way anteriorly to the pre-tracheal fascia and extending also from a point behind the clavicle and first rib well up onto the thyroid cartilage, that one is able to demonstrate conclusively the presence or absence of a divided recurrent laryngeal nerve

There are those who feel that the routine dissection of the recurrent laryngeal nerves at the time of operation is the best method of prevention of damage to these structures. Once again, perusal of the accompanying diagrams will serve to justify the conclusion that it is only in the cadaver that a sufficiently wide dissection may be made. We do not feel that it is practical, where the primary mission of the operation is the removal of the thyroid gland, to make such a wide dissection to isolate completely the recurrent laryngeal nerves, and yet our dissecting room experience clearly shows that one may be deceived into believing he has dissected out the entire recurrent laryngeal nerve where actually he has only exposed one of its branches A wider dissection would reveal the presence of one or more branches

Additionally, the complete dissection of the recurrent laryngeal nerves, in order to avoid damage to these structures, is attendant with a certain amount of troublesome bleeding. It is impossible to carry out such a dissection without severance of multiple branches to the trachea and esophagus It is problematical just how important these small filaments might be, but it seems difficult to justify their indiscriminate severance in order to completely expose all of the component branches of the recurrent laryngeal nerve

CHAPTER 4

Clinical Considerations

WE HAVE observed no consistency whatsoever in the nerve patterns between right and left sides To cite a few examples, experience has not shown that because an individual has a single trunk nerve on one side, of necessity he has a single trunk nerve on the opposite side. Conversely, the presence of a branched nerve on one side does not indicate that he may have a branched nerve on the opposite side, nor does the presence of a nerve divided into two branches on one side indicate that he may have a nerve divided into two branches on the opposite side. Indeed, he may have four or five or even six branches on the opposite side. The recurrent laryngeal nerve, whether as a main single trunk or whether broken up into a variable number of component branches, has been seen to enter into many, diverse and completely unpredictable branching patterns

Fowler and Hansen (8) laid considerable stress on the vulnerable point in the neck during the course of operations on the thyroid gland where the recurrent nerve might most likely be damaged. These authors state that "in a large majority of cases the most intimate relation between the gland and the nerve was not at the lower pole as is generally assumed, but rather at the postero-lateral surface at the junction of the middle and lower third, right at or just above the point where the chief branches of the inferior thyroid artery enter the gland"

TABLE IV

LOCATION OF DIVISIONS OF NERVES

(86 Nerves)

Superior Thyroid Level	21	24 2%
Thyroid Level	47	54.7%
Inferior Thyroid Level	18	20 9%

With this statement we are in full agreement. They further state that the nerve is often in extremely intimate relationship to the gland substance on its posterior surface, an observation which coincides with our own

Berlin and Lahey (2) in 1929 reported on dissections of the recurrent laryngeal nerves and again in 1935 Berlin (3) published a further report on

this structure. We are in disagreement with the concept that the recurrent laryngeal nerve ever penetrates the substance of the thyroid gland. We have seen instances where adenomas have appeared to grow around or curve around the main trunk of the recurrent laryngeal nerve, but careful dissection has proven that the nerve did not penetrate the gland substance proper, even though it was obviously in close relationship. Embryologically, we consider that it is impossible for the recurrent laryngeal nerve to traverse the gland parenchyma. We, however, are in agreement with these authors when they say that the inferior cornu of the thyroid cartilage represents a good landmark for the location of this nerve, since the recurrent laryngeal nerve generally passes just posterior to this articulation.

The author feels that it would be extremely easy to miss the presence of a divided nerve in the live patient during the course of operation, for the surgeon, quite naturally, upon discovering a branch of the recurrent nerve trunk, would presume this to be the nerve *in toto* and would terminate his dissection rather than lay open all the tissue spaces in the neck in search of a possible second or third branch. It is therefore only in the cadaver where the entire area extending from the pre-vertebral fascia all the way anteriorly to the pre-tracheal fascia and extending also from a point behind the clavicle and first rib well up onto the thyroid cartilage, that one is able to demonstrate conclusively the presence or absence of a divided recurrent laryngeal nerve.

There are those who feel that the routine dissection of the recurrent laryngeal nerves at the time of operation is the best method of prevention of damage to these structures Once again, perusal of the accompanying diagrams will serve to justify the conclusion that it is only in the cadaver, that a sufficiently wide dissection may be made. We do not feel that it is practical, where the primary mission of the operation is the removal of the thyroid gland, to make such a wide dissection to isolate completely the recurrent laryngeal nerves, and yet our dissecting room experience clearly shows that one may be deceived into believing he has dissected out the entire recurrent laryngeal nerve where actually he has only exposed one of its branches. A wider dissection would reveal the presence of one or more branches.

Additionally, the complete dissection of the recurrent laryngeal nerves, in order to avoid damage to these structures, is attendant with a certain amount of troublesome bleeding It is impossible to carry out such a dissection without severance of multiple branches to the trachea and esophagus It is problematical just how important these small filaments might be, but it seems difficult to justify their indiscriminate severance in order to completely expose all of the component branches of the recurrent laryngeal nerve

Looking over the imposing roster of names of anatomists and clinicians who have exhibited a lively interest on the subject of recurrent laryngeal nerves, one is impressed with the consistency with which these men have statistically emphasized the position of the recurrent laryngeal nerve in relation to the inferior thyroid artery. A number of these authors have taken a somewhat dogmatic stand as to whether or not the nerve crosses anterior to the inferior thyroid artery, or posterior to that vessel.

For example, Gray and also Davis state that the recurrent laryngeal nerve generally passes posterior to the inferior thyroid artery, while Cunningham states that the recurrent nerve may go either way, there being no difference in the right or left sides Lahey states that the recurrent nerve is more often anterior to the inferior thyroid artery on the right and posterior to this vessel on the left. DeQuervain agrees with this distribution of nerve and artery and relationship, while Nordland (37) states very positively that there are absolutely no constant differences in relationship between the inferior thyroid artery and the recurrent laryngeal nerves, and therefore does not agree with those who say there are.

From the foregoing, it is evident that there is no universal agreement. We are of the opinion, and therefore in agreement with Nordland, that there are no constant differences in relationship upon which one may firmly depend in the performance of thyroid surgery, that one may find a nerve that has branched two or more times on one side, while finding a single trunk on the other side Furthermore, these branches or principal trunks may, and often do, intertwine between branches of the inferior thyroid artery and at one point lie anterior to it, while only a centimeter away, are lying directly posterior to the vessel

TABLE V

RELATION TO BRANCHES OF THE INFERIOR THYROID ARTERY
(200 Nerves)

	Anterior	*Between*	*Posterior*	*Parallel*
Right Single Trunk Nerves	19	9	18	10
Right Divided Trunk Nerves	17	17	20	8
Left Single Trunk Nerves	14	12	33	12
Left Divided Trunk Nerves	5	14	22	4
Total	55	52	93	34
Per Cent	27 5	26 0	46 5	17 0

We are also of the opinion that single filaments of a nerve with multiple branches are damaged more frequently than is supposed The reason that these injuries remain undiagnosed is due to the fact that the function of the vocal cords has not been grossly interrupted and therefore they assume no position of paralysis which may be observed at laryngoscopy. However, the

complaint of voice fatigue, we feel, is probably indicative of these injuries.

The question might be quite reasonably placed at this time: "How does one avoid damage to an anatomical structure so obscure and so variable?" The author is of the opinion that the best way to avoid damage to so variable an anatomical structure lies first in the awareness of the multiple anatomical possibilities of the structure involved, on the part of the surgeon. It is self-evident that a surgeon cannot look at the neck of an individual and divine whether the recurrent laryngeal nerve lies in front or in back of the inferior thyroid artery or whether it has one branch or many branches, but if he enters the operating theatre with the confidence which emanates from a real appreciation of the anatomy which the area to be operated upon presents, he will in the course of his own dexterity and educated watchfulness be able to carry out his dissections in such a way as either to stay away from danger areas, or, realizing that he is in an area which may potentially result in damage to the recurrent laryngeal nerves, carry out his dissection in such a meticulous fashion as to avoid accidental bleeding and blind application of clamps and injudicious use of mounted sutures. We realize that there will always be instances where injury to the recurrent laryngeal nerve cannot be avoided.

Secondly, the author is of the opinion that ligature of the inferior thyroid artery in selected cases as far laterally as possible will lessen the possibility of accidental hemorrhage in the vulnerable area without the complications which so frequently result. The lateral ligature of the inferior thyroid artery is done in an area where there is no likelihood of damage to the recurrent laryngeal nerve

The author cannot overemphasize the recommendation that all patients upon whom thyroid or neck surgery is contemplated, be subjected to preoperative and postoperative laryngoscopy. This is especially mandatory where the patient has had previous neck surgery. The medico-legal aspects of such a precautionary examination become clear when one sees malposition or malfunction of one or both vocal cords prior to surgery. Similarly, the postoperative examination of the larynx and vocal cords, is of equal importance It is possible for one to make an early diagnosis of nerve injury by such an examination, particularly when carried out in the immediate postoperative period and when repeated in six to eight hours and possibly again after twenty-four hours

Chapter 5

Illustrations

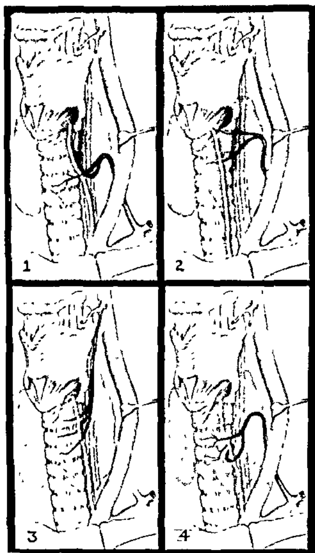
GROUP I

1. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. At the level of the thyroid space it comes into very close relationship with an ascending branch of the inferior thyroid artery. It pursues its cephalad course side by side and parallel to this vessel in close apposition to it. The opportunity for damage to this vessel is obviously great.

2. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. It occupies a relationship to the inferior thyroid artery as shown It also occupies a slightly forward position on the lateral tracheal wall

3. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. This specimen did not have an inferior thyroid artery and the entire circulation to the thyroid gland was taken over by the superior thyroid artery. The nerve crossed under the lowermost of these branches and over the other branches of the superior thyroid artery and in these locations occupies a close and intertwining relationship to the vessel

4. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. The manner in which the branches of the inferior thyroid artery are seen to wind tortuously around the nerve has resulted in a very close and intimate relationship of the nerve to the artery with a great potential for damage to the nerve



Group I

GROUP II

1. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. That branch of the inferior thyroid artery which is shown to ascend parallel to the recurrent laryngeal nerve is the largest of all the arterial branches and the nerve, where it crosses this branch, lies directly on top of it in a contiguous relationship to the vessel The relationship of the nerve to the branches of the artery is extremely intimate throughout, the nerve winding over and under and around the vessel, or vice versa.

2 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and once again occupies a very intimate relationship to the inferior thyroid artery and its branches, winding under and over the vessel as shown.

3 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and once again occupies a very intimate relationship to the inferior thyroid artery and its branches, winding under and over the vessel as shown.

4. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve throughout This specimen was unusual in that the nerve occupied an extremely high position on the trachea, lying on its antero-lateral surface. The artery entered the gland lateral and somewhat posterior and therefore there was no relationship between the nerve and the artery in this case The forward position of the nerve on the trachea is emphasized

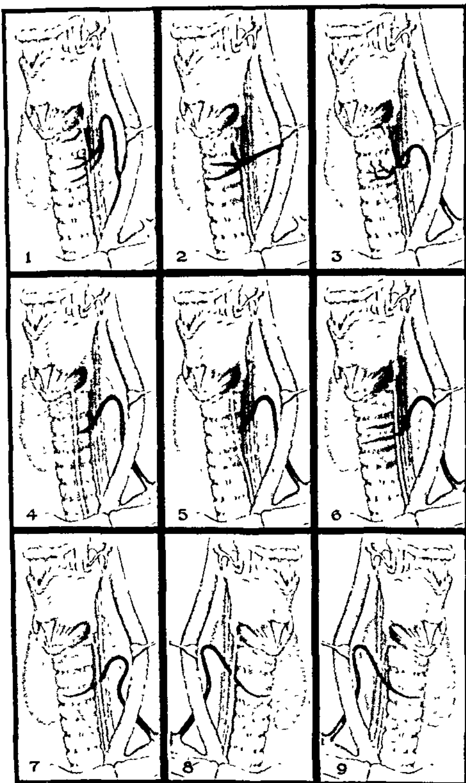
5 This specimen had a right sided aortic arch with the left laryngeal nerve assuming its recurrent course by turning under the ligamentum arteriosum on the left side The nerve on the right side, of course, assumed its recurrent course by turning under the right sided aortic arch

6 The recurrent laryngeal nerve ascended throughout as a single trunk nerve and occupies a position in the forked branch of the inferior thyroid artery crossing under the lower and over the upper branch of the vessel as shown.

7 The recurrent laryngeal nerve ascended as a single trunk nerve crossing over or anterior to the inferior thyroid artery

8 The recurrent laryngeal nerve ascends in the neck as a single trunk nerve throughout, crossing the inferior thyroid artery anteriorly, overlying the vessel just at the point where it enters the gland at its lateral border

9. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve throughout. This nerve occupies a position far posteriorly lying deep alongside the esophagus. The inferior thyroid artery crosses well anterior to the nerve



GROUP II

GROUP III

1. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve throughout. It lies superficial to the inferior thyroid artery, which vessel ran unusually high, even to the uppermost level of the superior pole of the gland and then coursed downward to the inferior pole.

2. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve throughout. As it emerges from the chest it lies high along the lateral tracheal wall in a very forward position As it dips under the lower pole of the thyroid gland its direction is more posteriorly. At the point where it comes in contact with the inferior thyroid artery, the artery at this point crosses under the nerve and immediately divides as shown. The ascending branch of the artery was a large vessel and this part of the artery and the recurrent laryngeal nerve ascended side by side in contiguous relationship.

3. The recurrent laryngeal nerve ascends as a single trunk nerve throughout. As it comes into relationship with the inferior thyroid artery it assumes a parallel course lying side by side with this vessel.

4 The recurrent laryngeal nerve ascends as a single trunk nerve throughout, crossing deep to the lowermost branch of the inferior thyroid artery and over the uppermost branches of this vessel.

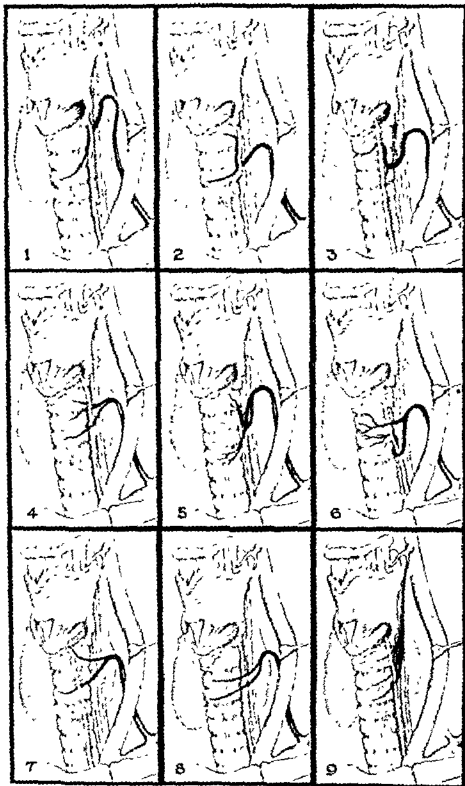
5. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its course, once again occupying very intimate relationships to a tortuous branched inferior thyroid artery

6 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its course, once again occupying very intimate relationships to a tortuous branched inferior thyroid artery.

7 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its course. This nerve occupies a forward position lying rather high or anteriorly on the lateral tracheal wall Prior to entering the larynx it lies in close apposition and parallel to the uppermost branch of the inferior thyroid artery in a vulnerable position

8. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its course, lying deep to the inferior thyroid artery and out of harm's way

9. There was a complete absence of an inferior thyroid artery The total circulation to the thyroid gland was taken over by the superior thyroid artery At the points where the nerve crosses under and over the branches of the artery, the relationship is very intimate and consequently opportunity for damage to the nerve in this situation is great



Group III

GROUP IV

1. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. At the point where the inferior thyroid artery comes into relationship with the nerve it can be seen that this relationship is extremely close and intimate. The nerve courses between and parallel to two branches of the artery, affording thereby a double opportunity for injury should it become necessary either to clamp or suture ligate these two vascular branches individually.

2. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. It crosses over and lies on top of all three branches of the inferior thyroid artery

3. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. As is seen, it crosses under, then over branches of the inferior thyroid and comes to lie side by side in contiguous relationship to the ascending branch of the inferior thyroid artery.

4. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. It crosses over the lowermost of the two branches of the inferior thyroid artery and under and parallel to an ascending branch of the artery.

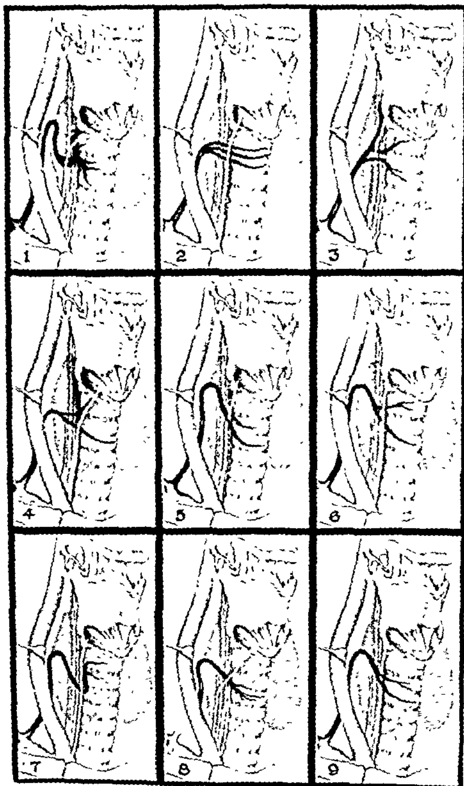
5 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and occupies a position in the forked branches of the inferior thyroid artery after crossing under the lower branch and over the upper branch of the vessel.

6 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course, and overlies the branches of the inferior thyroid artery.

7. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course It crosses over the main trunk of the inferior thyroid artery and ascends side by side with this vessel as the vessel ascends for a distance of two centimeters In this parallel relationship the two structures lie side by side

8. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course Behind the clavicle the nerve lies far posteriorly alongside the esophagus, but as it comes into the thyroid space it angulates anteriorly and assumes a remarkably superficial position high on the tracheal wall At the point where it crosses the inferior thyroid artery, the nerve lies directly over this vessel and in contact with it

9 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and crosses under both branches of the inferior thyroid artery



Group B

GROUP IV

1 *The recurrent laryngeal nerve ascends as a single trunk nerve throughout* its entire course. At the point where the inferior thyroid artery comes into relationship with the nerve it can be seen that this relationship is extremely close and intimate. The nerve courses between and parallel to two branches of the artery, affording thereby a double opportunity for injury should it become necessary either to clamp or suture ligate these two vascular branches individually.

2. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course It crosses over and lies on top of all three branches of the inferior thyroid artery.

3 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. As is seen, it crosses under, then over branches of the inferior thyroid and comes to lie side by side *in contiguous relationship to the ascending* branch of the inferior thyroid artery

4. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course. It crosses over the lowermost of the two branches of the inferior thyroid artery and under and parallel to an ascending branch of the artery.

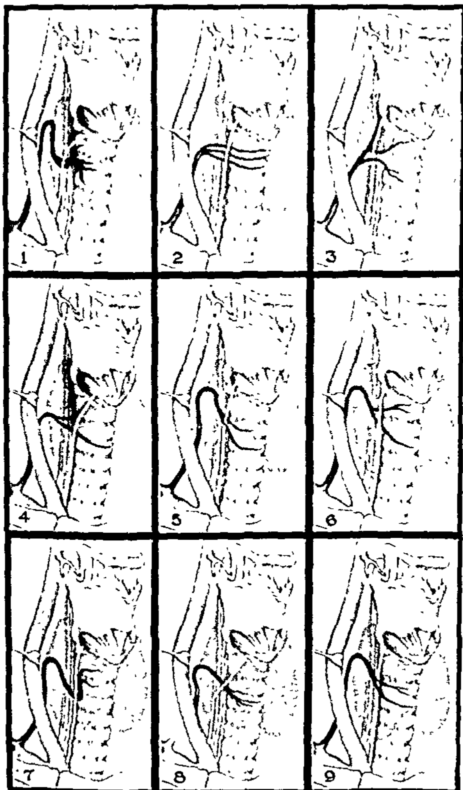
5 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and occupies a *position in the forked branches of the inferior* thyroid artery after crossing under the lower branch and over the upper branch of the vessel

6 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course, and overlies the branches of the inferior thyroid artery

7 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course It crosses over the main trunk of the inferior thyroid artery and ascends side by side with this vessel as the vessel ascends for a distance of two centimeters In this parallel relationship the two structures lie side by side

8 The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course Behind the clavicle the nerve lies far posteriorly alongside the esophagus, but as it comes into the thyroid space it angulates anteriorly and assumes a remarkably superficial position high on the tracheal wall At the point where it crosses the inferior thyroid artery, the nerve lies directly over this vessel and in contact with it

9. The recurrent laryngeal nerve ascends as a single trunk nerve throughout its entire course and crosses under both branches of the inferior thyroid artery



Group IV

GROUP V

1. The recurrent laryngeal nerve crosses under the inferior thyroid artery and divides into two branches before entering the larynx

2. The recurrent laryngeal nerve comes up as a single trunk with many branches to the trachea and esophagus and divides into its two terminal branches outside the larynx as shown.

3. The recurrent laryngeal nerve divides at the level of the lower pole of the thyroid gland and crosses over the lowermost branch of the inferior thyroid artery as a nerve divided into two trunks. The two terminal branches then cross deep to the upper two branches of the inferior thyroid artery. The nerve is very intimately related to the capsule of the thyroid gland on its posterior aspect, especially near the point where the terminal branches enter the larynx In fact, it may be said that a portion of the posterior capsule of the thyroid gland lies directly on the ascending branches of the recurrent laryngeal nerve.

4. The recurrent laryngeal nerve ascends as a single trunk and overlies the inferior thyroid artery hard alongside the trachea and thyroid gland. The nerve divides into its two terminal branches directly over the inferior thyroid artery, at which point the inferior thyroid artery is seen to enter the thyroid gland. It is noteworthy that the nerve takes a course from a position somewhat posterior to its lateral position much more anteriorly and enters the larynx at a markedly anterior point

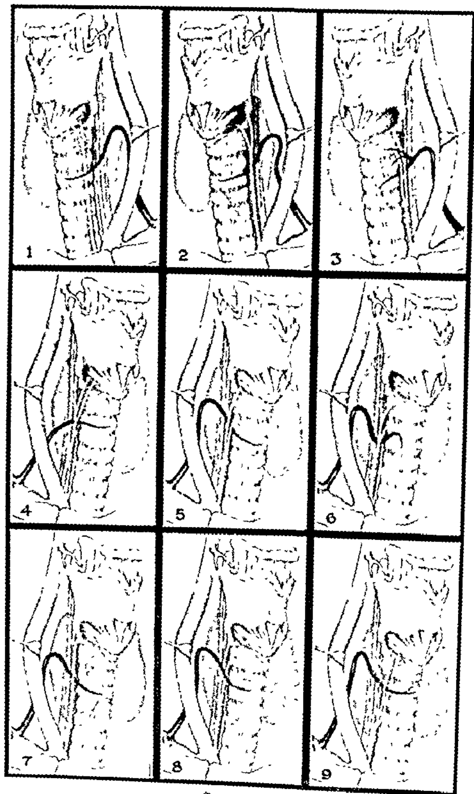
5 The recurrent laryngeal nerve ascends as a single trunk and divides into two terminal branches below the level at which it crosses anterior to the inferior thyroid artery.

6 The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches immediately over the inferior thyroid artery, to which it lies therefore immediately anterior

7 The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the thyroid space below the level of the inferior thyroid artery A longer branch seems to be the main trunk and crosses anterior to and therefore overlies the inferior thyroid artery A shorter branch is a somewhat thin trunk which ascends deep to the inferior thyroid artery

8. The recurrent laryngeal nerve ascends as a single trunk and divides into two terminal branches in the inferior thyroid space Both branches ascend deep to the inferior thyroid artery

9 The recurrent laryngeal nerve ascends into the neck in a posterior position and divides into its two terminal branches at a low level in the inferior thyroid space. One terminal branch crosses over and the other terminal branch crosses under the inferior thyroid artery Both branches pursue their cephalad course in a closely parallel position



Group V

GROUP V

1. The recurrent laryngeal nerve crosses under the inferior thyroid artery and divides into two branches before entering the larynx.

2. The recurrent laryngeal nerve comes up as a single trunk with many branches to the trachea and esophagus and divides into its two terminal branches outside the larynx as shown.

3 The recurrent laryngeal nerve divides at the level of the lower pole of the thyroid gland and crosses over the lowermost branch of the inferior thyroid artery as a nerve divided into two trunks. The two terminal branches then cross deep to the upper two branches of the inferior thyroid artery. The nerve is very intimately related to the capsule of the thyroid gland on its posterior aspect, especially near the point where the terminal branches enter the larynx. In fact, it may be said that a portion of the posterior capsule of the thyroid gland lies directly on the ascending branches of the recurrent laryngeal nerve.

4 The recurrent laryngeal nerve ascends as a single trunk and overlies the inferior thyroid artery hard alongside the trachea and thyroid gland. The nerve divides into its two terminal branches directly over the inferior thyroid artery, at which point the inferior thyroid artery is seen to enter the thyroid gland It is noteworthy that the nerve takes a course from a position somewhat posterior to its lateral position much more anteriorly and enters the larynx at a markedly anterior point

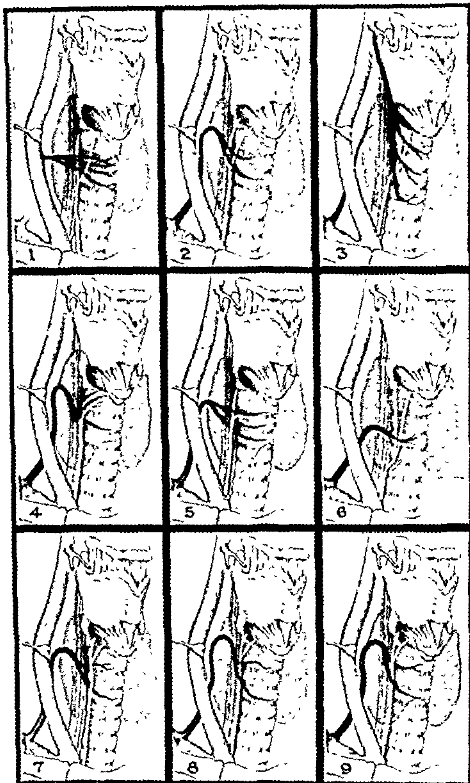
5. The recurrent laryngeal nerve ascends as a single trunk and divides into two terminal branches below the level at which it crosses anterior to the inferior thyroid artery.

6 The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches immediately over the inferior thyroid artery, to which it lies therefore immediately anterior

7. The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the thyroid space below the level of the inferior thyroid artery A longer branch seems to be the main trunk and crosses anterior to and therefore overlies the inferior thyroid artery A shorter branch is a somewhat thin trunk which ascends deep to the inferior thyroid artery

8 The recurrent laryngeal nerve ascends as a single trunk and divides into two terminal branches in the inferior thyroid space Both branches ascend deep to the inferior thyroid artery

9. The recurrent laryngeal nerve ascends into the neck in a posterior position and divides into its two terminal branches at a low level in the inferior thyroid space One terminal branch crosses over and the other terminal branch crosses under the inferior thyroid artery Both branches pursue their cephalad course in a closely parallel position



Group VI

GROUP VI

1. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve occupying a position somewhat more anterior than usual, which is to say anterior to the tracheo-esophageal groove actually along the wall of the trachea. It divides into two terminal branches in the thyroid space and the two branches cross over and under and in between the several terminal branches of the inferior thyroid artery as indicated. In all its course the nerve is in very intimate and close relationship to the inferior thyroid artery and its branches, to the thyroid gland, and occupies a vulnerable position throughout.

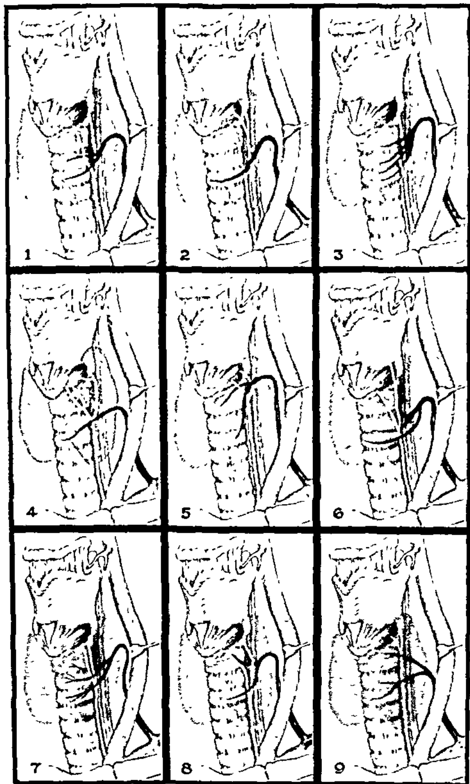
2. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve and divides into two terminal branches in the thyroid space at the level where the inferior thyroid artery crosses over it. The nerve and its branches lies deep to the artery and in general occupies a posterior position not likely to be damaged.

3. This specimen had a very thin filamentous vessel that corresponded to an inferior thyroid artery which in the dissecting room could not be traced all the way to the thyroid gland because of the tiny branches which could not be dissected. The superior thyroid artery was a large vessel and was seen to proceed all the way to the lower pole of the thyroid gland and undoubtedly carried all of the blood supply to the thyroid gland. The recurrent laryngeal nerve ascended as a single trunk nerve and divided in the thyroid space into its two terminal branches after having curved forward to an anterior position The nerve occupied a position deep to the superior thyroid artery.

4 The recurrent laryngeal nerve ascended in the neck to the thyroid space where it divided into its two terminal branches at the point where it came into contiguous relationship with the terminal branches of the inferior thyroid artery At the point where the two terminal branches of the recurrent laryngeal nerve and the two terminal branches of the inferior thyroid artery appear to angle forward and medially the branches of the artery actually lay directly on top and in contact with the branches of the nerve As they proceed the nerves enter the larynx and the overlying vascular branches enter the thyroid gland In such an intimate side by side relationship possibilities for nerve damage would be avoided with difficulty

5. The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the thyroid space at the precise point where it overlies the lowermost branch of the inferior thyroid artery The two nerve branches continue cephalad side by side and cross over and therefore overlie the middle branch of the inferior thyroid artery The posterior branch is seen to dip underneath the uppermost branch of the inferior thyroid artery while the anterior branch of the nerve turns anteriorly and for a short distance lies parallel to the uppermost branch of the inferior thyroid artery before entering the larynx

6 This cadaver had a right sided aortic arch The left recurrent laryngeal nerve assumed its recurrent course around the ligamentum arteriosum while the right nerve assumed its recurrent course under the right sided aortic arch. In this instance the recurrent laryngeal nerve ascended into the neck as shown and divided into its two terminal branches in the inferior thyroid space crossing under the inferior thyroid artery



Group VII

7. The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the superior thyroid space. It crosses over and therefore lies anterior to the inferior thyroid artery.

8. The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the superior thyroid space. It crosses deep to the inferior thyroid artery

9. The recurrent laryngeal nerve ascends as a single trunk nerve and divides into its two terminal branches in the superior thyroid space. The nerve lies in between the forked branches of the recurrent laryngeal nerve crossing under the lower branch and over the upper branch of this vessel.

GROUP VII

1. The recurrent laryngeal nerve ascends in the neck and divides in the thyroid space as shown. The more anterior of the two branches seems to be the main trunk of the nerve and ascends between the terminal branches of the inferior thyroid artery The more posterior of the terminal branches is a small branch which angles off posteriorly and ascends up the side of the larynx and lies deep or posterior to the inferior thyroid artery well out of harm's way.

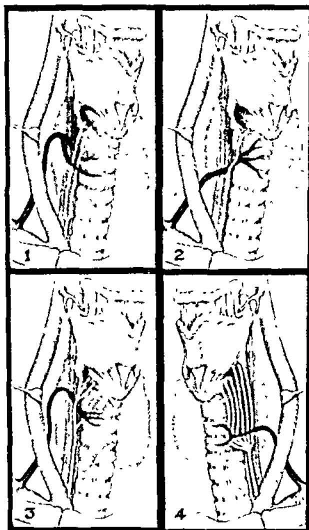
2. The recurrent laryngeal nerve ascends from the arch of the aorta to a level behind the clavicle, at which point it divides into two terminal branches. The two terminal branches continue their cephalad direction both of which lie well posterior to the inferior thyroid artery. Of the two terminal branches, the posterior one re-divides again before entering the larynx

3 The recurrent laryngeal nerve ascends as a single trunk and divides into two terminal branches in the inferior thyroid space The anterior of the two terminal branches crosses over the lowermost ramus of the inferior thyroid artery and under the next three rami of this vessel The posterior of the two terminal branches crosses behind and therefore under or posterior to all branches of the inferior thyroid artery

4. The recurrent laryngeal nerve ascends in the neck and divides into two major branches just underneath the point where the inferior thyroid artery crosses over the nerve, approximately one centimeter lateral to the lateral border of the thyroid gland The two major branches then re-divide, resulting in four extralaryngeal branches of the recurrent laryngeal nerve, all of which enter the larynx as indicated

5. The recurrent laryngeal nerve ascends deep in the tracheal-esophageal groove as a single trunk nerve As it approaches the superior thyroid space on the posterior surface of the thyroid gland, with which it bears an intimate relationship, it divides into two branches which are terminal The anterior-most branch ascends between two branches of the inferior thyroid artery, crosses under one branch of this vessel and over another while the posterior-most branch of the recurrent laryngeal nerve simply continues its ascent well out of the way The inferior thyroid artery approaches the thyroid gland from the usual lateral position, running medialward on the posterior or under surface of the gland

6 The recurrent laryngeal nerve ascends as a single trunk nerve to the level



Group VIII

space, where it divides into two terminal branches The posterior branch continues its cephalad course and crosses over the inferior thyroid artery, re-dividing into three branches extralaryngeally The anterior branch crosses under the terminal branches of the inferior thyroid artery and re-divides at this point into two terminal branches, resulting in a total of five branches of the recurrent laryngeal nerve which have divided outside the larynx.

4 The recurrent laryngeal nerve ascends in the neck as a single trunk nerve to a point approximately two centimeters below the point where the inferior thyroid artery crosses transversely over the nerve to enter the thyroid gland. At the point of division it divides immediately into six terminal filaments all of which were seen to enter the larynx The nerve was at all times deep to the artery

of the inferior thyroid space, where it divides into its two terminal branches as indicated. The recurrent laryngeal nerve passes under the lowermost of the terminal branches of the inferior thyroid artery as a single trunk nerve, immediately after which it divides into its two terminal branches both of which cross over or anterior to the middle branch of the inferior thyroid artery. The more posterior of the two branches continues its cephalad ascent lying parallel to an ascending branch of the inferior thyroid artery for an appreciable distance. One can easily visualize the hazard to this nerve should this branch of the inferior thyroid artery be accidentally severed.

7. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve and divides in the thyroid space into its two terminal branches as indicated. It is in intimate relationship with the branches of the inferior thyroid artery lying deep or immediately posterior to the lowermost two branches and crossing over the uppermost branch of the inferior thyroid artery.

8 The recurrent laryngeal nerve ascends in the neck as a single trunk and divides into two terminal branches in the inferior thyroid space just below the point at which it crosses under the lowermost branch of the inferior thyroid artery. As these two terminal branches ascend they come into intimate relationship with the two upper branches of the inferior thyroid artery and the four structures not only lie side by side but pursue a parallel course one with the other as shown. Here again it is easy to visualize the opportunity for damage to the recurrent laryngeal nerve in this situation. The branches of the recurrent laryngeal nerve and the upper branches of the inferior thyroid artery are actually contiguous to each other

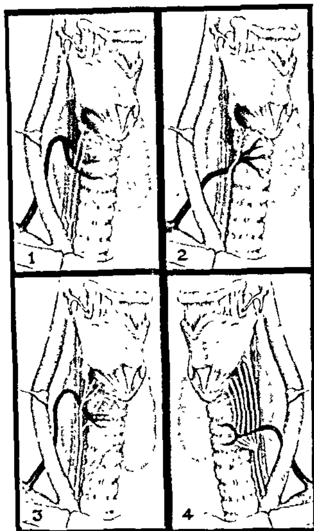
9 The recurrent laryngeal nerve ascends as a single trunk nerve and divides into two terminal branches in the superior thyroid space immediately before entering the larynx The nerve lies deep to the inferior thyroid artery throughout its entire course

GROUP VIII

1 The recurrent laryngeal nerve was found to divide into two terminal branches at a point directly behind the clavicle. (The illustration shows the nerve branching at a slightly higher level but the actual point of division was found to be lower, namely behind the clavicle.) The two branches continue their cephalad course, crossing under the lower branch of the inferior thyroid artery and over the upper branch of the inferior thyroid artery lying therefore in the fork of the terminal branches of the inferior thyroid artery

2. The recurrent laryngeal nerve ascends in the neck as a single trunk and divides into its two terminal branches immediately before entering the larynx. As it crosses over the inferior thyroid artery it comes into a relationship with this vessel in which it lies directly on top of the inferior thyroid artery, actually in contact with this vessel While lying on top of the vessel it also takes a parallel course to the vessel for a short distance as shown At this point the recurrent laryngeal nerve and the inferior thyroid artery are contiguous to each other

3 The recurrent laryngeal nerve ascends in the neck to the level of the thyroid



GROUP VIII

space, where it divides into two terminal branches The posterior branch continues its cephalad course and crosses over the inferior thyroid artery, re-dividing into three branches extralaryngeally The anterior branch crosses under the terminal branches of the inferior thyroid artery and re-divides at this point into two terminal branches, resulting in a total of five branches of the recurrent laryngeal nerve which have divided outside the larynx.

4 The recurrent laryngeal nerve ascends in the neck as a single trunk nerve to a point approximately two centimeters below the point where the inferior thyroid artery crosses transversely over the nerve to enter the thyroid gland. At the point of division it divides immediately into six terminal filaments all of which were seen to enter the larynx The nerve was at all times deep to the artery.

of the inferior thyroid space, where it divides into its two terminal branches as indicated. The recurrent laryngeal nerve passes under the lowermost of the terminal branches of the inferior thyroid artery as a single trunk nerve, immediately after which it divides into its two terminal branches both of which cross over or anterior to the middle branch of the inferior thyroid artery. The more posterior of the two branches continues its cephalad ascent lying parallel to an ascending branch of the inferior thyroid artery for an appreciable distance. One can easily visualize the hazard to this nerve should this branch of the inferior thyroid artery be accidentally severed.

7. The recurrent laryngeal nerve ascends in the neck as a single trunk nerve and divides in the thyroid space into its two terminal branches as indicated. It is in intimate relationship with the branches of the inferior thyroid artery lying deep or immediately posterior to the lowermost two branches and crossing over the uppermost branch of the inferior thyroid artery.

8 The recurrent laryngeal nerve ascends in the neck as a single trunk and divides into two terminal branches in the inferior thyroid space just below the point at which it crosses under the lowermost branch of the inferior thyroid artery As these two terminal branches ascend they come into intimate relationship with the two upper branches of the inferior thyroid artery and the four structures not only lie side by side but pursue a parallel course one with the other as shown Here again it is easy to visualize the opportunity for damage to the recurrent laryngeal nerve in this situation. The branches of the recurrent laryngeal nerve and the upper branches of the inferior thyroid artery are actually contiguous to each other

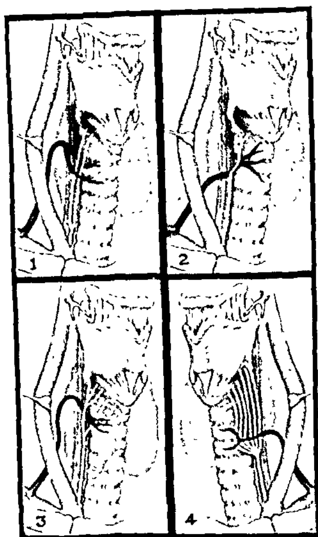
9 The recurrent laryngeal nerve ascends as a single trunk nerve and divides into two terminal branches in the superior thyroid space immediately before entering the larynx The nerve lies deep to the inferior thyroid artery throughout its entire course

GROUP VIII

1 The recurrent laryngeal nerve was found to divide into two terminal branches at a point directly behind the clavicle (The illustration shows the nerve branching at a slightly higher level but the actual point of division was found to be lower, namely behind the clavicle) The two branches continue their cephalad course, crossing under the lower branch of the inferior thyroid artery and over the upper branch of the inferior thyroid artery lying therefore in the fork of the terminal branches of the inferior thyroid artery

2 The recurrent laryngeal nerve ascends in the neck as a single trunk and divides into its two terminal branches immediately before entering the larynx As it crosses over the inferior thyroid artery it comes into a relationship with this vessel in which it lies directly on top of the inferior thyroid artery, actually in contact with this vessel While lying on top of the vessel it also takes a parallel course to the vessel for a short distance as shown At this point the recurrent laryngeal nerve and the inferior thyroid artery are contiguous to each other

3 The recurrent laryngeal nerve ascends in the neck to the level of the thyroid



GROUP VIII

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4 The recurrent laryngeal nerve ascends in the neck as a single trunk nerve to a point approximately two centimeters below the point where the inferior thyroid artery crosses transversely over the nerve to enter the thyroid gland. At the point of division it divides immediately into six terminal filaments all of which were seen to enter the larynx. The nerve was at all times deep to the artery

GROUP IX

1. The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the lower pole of the thyroid gland. At this point it divides extralaryngeally into three terminal branches The three branches cross over the lower branch of *the inferior thyroid* artery and under the upper branch They therefore lie between the two branches of the artery.

2 The recurrent laryngeal nerve ascends as a single trunk nerve to a point low in the neck at the lower extremity of the inferior pole of the thyroid gland where it divides into two terminal branches. The anterior of these two branches *re-divides into two terminal* branches, resulting in three extralaryngeal branches traversing the thyroid space. All branches lie deep to the inferior thyroid artery.

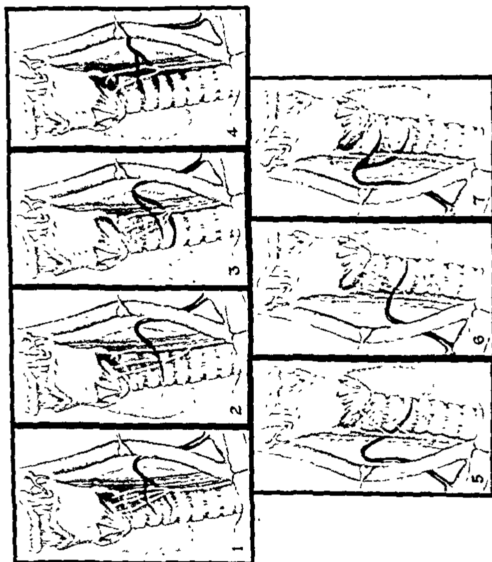
3 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space, where it divides extralaryngeally into three terminal branches. All three branches cross over or anterior to the lower branch of the inferior thyroid artery and under the upper branch of this vessel.

4 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space, where it divides into two terminal branches These branches *course at first over, then under the terminal branches of the inferior thyroid* artery, posterior of these two nerve branches re-divides into two branches as shown, resulting in three extralaryngeal terminal branches of the nerve

5 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides into two branches The posterior of these two branches re-divides into two branches resulting in three extralaryngeal terminal branches of the recurrent laryngeal nerve. The nerve lies on top of the inferior thyroid artery at the points of crossing It is obvious that a clamping of the vessel in these situations would also result in clamping of the nerve

6 The recurrent laryngeal nerve ascends as a single trunk nerve into the thyroid space where it divides into three terminal branches which traverse this and the superior thyroid space The nerve occupies a posterior position throughout in relation to the inferior thyroid artery, the artery therefore crossing over all branches of the nerve

7. The recurrent laryngeal nerve ascends as a single trunk nerve to the thyroid space where it divides into three terminal branches It bears the relationship to the inferior thyroid artery as shown



Group IX

GROUP X

1. The recurrent laryngeal nerve ascends into the neck as a single trunk nerve After it crosses under the inferior thyroid artery it divides into four terminal branches which enter the larynx as indicated

2 The recurrent laryngeal nerve ascends as a single trunk nerve In the superior thyroid space, after crossing over two branches of the inferior thyroid artery in very close and intimate relationship to these two branches, it divides extralaryngeally into four terminal branches

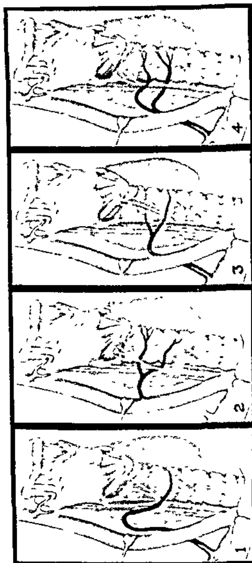
3. The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides extralaryngeally into four terminal branches

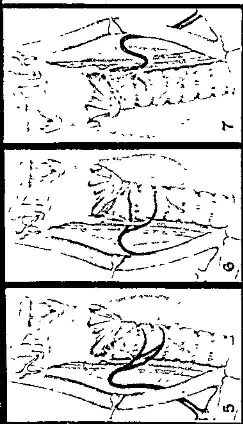
4 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides into two terminal branches The main trunk of the nerve crosses over the lower branch of the inferior thyroid artery and under the upper branch of this vessel The posterior branch of the nerve re-divides extralaryngeally into three branches, resulting in four extralaryngeal branches of the nerve

5 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space, where it divides into two branches. The anterior branch re-divides into three branches, resulting in four extralaryngeal branches of the nerve

6 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides into two branches The branches re-divide as indicated into four extralaryngeal branches prior to entering the larynx The nerve at all points lies deep to the inferior thyroid artery

7 The recurrent laryngeal nerve ascends in the neck to the level of the thyroid space as a single trunk nerve, at which point it divides extralaryngeally into four terminal branches The main trunk of the nerve is found to run parallel to the inferior thyroid artery for two centimeters before dividing and is in close apposition to it The branches cross over and under the artery as shown





Group X

GROUP X

1. The recurrent laryngeal nerve ascends into the neck as a single trunk nerve After it crosses under the inferior thyroid artery it divides into four terminal branches which enter the larynx as indicated

2 The recurrent laryngeal nerve ascends as a single trunk nerve. In the superior thyroid space, after crossing over two branches of the inferior thyroid artery in very close and intimate relationship to these two branches, it divides extralaryngeally into four terminal branches.

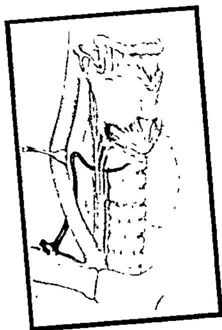
3 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides extralaryngeally into four terminal branches.

4 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides into two terminal branches The main trunk of the nerve crosses over the lower branch of the inferior thyroid artery and under the upper branch of this vessel The posterior branch of the nerve re-divides extralaryngeally into three branches, resulting in four extralaryngeal branches of the nerve.

5. The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space, where it divides into two branches The anterior branch re-divides into three branches, resulting in four extralaryngeal branches of the nerve

6 The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the thyroid space where it divides into two branches The branches re-divide as indicated into four extralaryngeal branches prior to entering the larynx The nerve at all points lies deep to the inferior thyroid artery

7. The recurrent laryngeal nerve ascends in the neck to the level of the thyroid space as a single trunk nerve, at which point it divides extralaryngeally into four terminal branches The main trunk of the nerve is found to run parallel to the inferior thyroid artery for two centimeters before dividing and is in close apposition to it The branches cross over and under the artery as shown



Group XI

GROUP XI

1. The recurrent laryngeal nerve ascends as a single trunk nerve to the level of the inferior thyroid space where it divides into four terminal branches The anteriormost of the four terminal nerve branches crosses under the inferior thyroid artery, while the other three branches cross over or anterior to this vessel.

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Conclusions

1. The function of the larynx and the individual functions of the participating muscles are described.

2. The line of supply to these muscles as we now know it is described

3 In this study of 200 recurrent laryngeal nerves, 114 or 57% were found to be single trunk nerves. Eighty-six or 43% were found to be divided nerves

4. The recurrent laryngeal nerve was found to undergo bilateral division in 24% of the specimens examined

5 The recurrent laryngeal nerve may branch at any point peripheral to its point of initial separation from the parent vagus nerve.

6 There is no consistency in the nerve pattern between right and left sides.

7 The point at which the recurrent laryngeal nerve is most vulnerable *to injury is on the postero-lateral surface of the thyroid gland at the level* of the junction of middle and lower thirds where the chief branches of the inferior thyroid artery usually enter the gland

8 It has been shown that secondary and tertiary divisions of the recurrent laryngeal nerve occur extralaryngeally.

9 The presence of these secondary and tertiary divisions in this vulnerable area offers an adequate explanation for the more complex and heretofore controversial types of laryngeal paralyses The explanation is based entirely on injury to the recurrent laryngeal nerve or its branches

10 Injury to one branch of a multi-branched nerve will produce paralysis only in the area supplied by that branch In some instances, only a single muscle or a portion of a muscle may be supplied by this branch.

11. The results of this study confirm the contributions made by Brien T King, M.D

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By

WILLIAM H. RUSTAD, M.D

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